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ORIGINAL ARTICLE

Combining the multi-level perspective framework with participatory scenario development to explore the many facets of food system transitions in Germany

Valentin Fiala[1] · **Klaus Jacob**[2]

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Abstract

Transitions to more sustainable food systems are urgently needed, but they are also very complex and hard to achieve. The integration of transdisciplinary approaches into transition research can help to understand and promote sustainable food system transitions, but remains an agenda item in this research field. To fill this gap, this article describes how the multi-level perspective (MLP) can be used as a framework for explorative, participatory scenario development. On the one hand, MLP provides scholars with a framework for understanding the dynamics of transitions. On the other hand, participatory scenario development brings together academic and non-academic actors and perspectives to explore and promote possible development pathways. Based on this framework, researchers and practitioners jointly co-created four scenarios of how the landscape of five relevant European food innovations located in established food systems or niches (alternative sources of proteins, prosumer initiatives, regional value chains, school meal programs, and dietary interventions) might change by 2040 and further explored how these food innovations might evolve under the scenarios. The results provide initial insights into the role that food innovations could play in different transition pathways and also indicate the value of a diverse portfolio of food innovations to respond to changing circumstances. Furthermore, the process allowed participants to develop a shared understanding of food system dynamics and explore potential future risks and opportunities for food innovations, showing that participatory scenarios based on the MLP framework are a useful lens for exploring sustainable food system transitions.

Keywords Sustainable transitions · Multi-level-perspective · Participatory scenario development · Food systems · Food innovations

Introduction

Megatrends such as population growth, globalization, changing lifestyles, or technological advances have dramatically transformed food systems around the world. As a result, modern, industrialized food systems embody "the productivist paradigm rooted in the green revolution, in which food systems enact an industrial approach to food and farming" (Gaitán-Cremaschi et al. 2019, p. 2). Innovations such as mechanization, new breeds, and synthetic pesticides and fertilizers have increased the productivity of agriculture in many parts of the world (Mazoyer and Roudart 2006; Tilman et al. 2002). However, contemporary food systems are also heavily criticized for their negative ecological (Baroni et al. 2007; Ramankutty et al. 2018) and social (Härlin and Beck 2013; Shiva 1991) impacts and face severe challenges, risks, and uncertainties (see e.g., FAO 2017).

Therefore, many authors see the need for fundamental change and a transition to more socially just and sustainable food systems. (see e.g., Feola 2015; Hubeau et al. 2017; Hinrichs 2014; Holt-Gimenez and Altieri 2013). How such a transition can be achieved is hotly debated, and very broadly two main lines of thinking can be identified. First, sustainable intensification seeks technological solutions and optimization within the given socio-economic context

Handled by Alexandros Gasparatos, University of Tokyo, Japan.

Valentin Fiala
v.fiala@boku.ac.at

Klaus Jacob
Klaus.Jacob@zalf.de

[1] University for Natural Resources and Life Science Vienna, Gregor-Mendelstraße 33, 1180 Vienna, Austria

[2] Leibniz Centre for Agricultural Landscape Research (ZALF), Eberswalder Straße 84, 15374 Müncheberg, Germany

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of the existing food system. This line of thinking promotes incremental changes and innovations leading to improved performance of food systems (Levidov 2018). In contrast, agroecology or the new rural paradigm (Mardsen 2012) calls for a more fundamental change in the socio-economic structures of food systems as well as more radical and also social innovations (Constance et al. 2018; Juarez et al. 2018; Jacob and Ekins 2020).

Because of the complexity of food systems,[1] a transition toward more sustainable food systems is hard to steer (Jacob and Ekins 2020) and can be seen as a great challenge of the twenty-first century (Feola 2015). The reasons for this are, first, that a variety of interrelated issues based on dispersed knowledge need to be addressed by a variety of policy makers and other actors (De Smedt et al. 2013). Second, past developments in food systems lead to entrenched processes and structures in established food systems. The resulting lock-ins inhibit radical change, innovation, and transformation (Gaitán-Cremaschi et al. 2019). To support both approaches mentioned above, as well as the transition to a sustainable food system in general, research needs a "significant prospective disposition" (Turnheim et al. 2015, p. 248), namely, they should prove helpful to explore or envision the future (see e.g., Rotmans et al. 2001; De Smedt et al. 2013)—and should be open for multi-stakeholder participation and engagement (see e.g., Grin et al. 2010; Köhler et al. 2019). To achieve both, conceptual tools to understand the dynamics, lock-ins, and other aspects that characterize the transition, as well as transdisciplinary approaches to engage stakeholders to identify and promote desirable future development pathways in collaboration with affected actors, are helpful (see Hirsch-Hadorn et al. 2008b; Nevens et al. 2013). Although interest in this regard is growing (see below), bringing transdisciplinarity into sustainability transition research has not often been achieved and remains a major item on the agenda of this research field (Köhler et al. 2019). There is still work to be done to connect participatory, future-orientated approaches from other fields of transdisciplinary sustainability science to important core concepts of sustainability transition research. Such a transfer could not only help to better understand transitions, but also engage actors in related issues.

To contribute to closing this gap and to enrich the toolkit for sustainability science on food system transitions, this article shows how transdisciplinary, participatory scenario development can be embedded in the multi-level perspective (MLP). The former is a stakeholder engagement tool widely used in transdisciplinary research (Chermack 2004; Wiek et al. 2006). The latter is one of the core frameworks of sustainable transition research used to understand the dynamics and structures of long-term system transitions.

The MLP is widely used to understand long-term transitions, but the majority of MLP studies focuses more on past than on future developments (Vähäkari et al. 2020). In addition, to our knowledge, the MLP is not often used in transdisciplinary research, which focuses on the integration academic and non-academic knowledge as well as the overcoming of practice relevant problems (Lang et al. 2012). Transdisciplinary, participatory scenario development approaches are often based on a systems framework (Wiek et al. 2006), but not the MLP.

The main contribution of this article is to show in detail how MLP-based transdisciplinary scenario development can be used to explore potential future pathways for food innovations in the context of sustainable transitions. By doing so, we present a refined lens to understand and promote sustainable food system transition. We hypothesize that the MLP can provide a robust framework for participatory scenario development and that participatory scenario development can provide meaningful results and additional benefits for MLP research. To this end, we first explain how MLP can provide the underlying structure for participatory scenario development. As a proof of concept, we then illustrate these ideas with the results of a recent research project aimed at understanding the potential contribution of food innovations to the transition to inclusive and sustainable food systems. In this project, researchers and practitioners collaborated to develop four different scenarios that show how the landscapes of food systems could evolve by 2040 in Germany. These scenarios were then used to anticipate potential risks and opportunities for food systems and explore transition pathways for related innovations. The German food system is highly developed, specialized, concentrated, and embedded in international trade (Schrode et al. 2019). It is therefore a good example for modern food systems with their dynamics and lock-ins described above (see Marshall et al. 2021). Based on these results, we discuss benefits as well as challenges of bringing the two approaches together. In addition to this theoretical discussion, this article offers some guidance in the complex field of current food innovations and provides food for thought on the multiple roles these innovations could play in the transition to more sustainable food systems.

Material and methods

Research approach

Along with other core approaches such as technological innovation systems (e.g., Hekkert et al. 2007), strategic niche management (Rip and Kemp 1998) and transition

[1] Food systems can be defined as all actors, activities, and structures associated with processing, distribution, consumption, and disposal of food as well as the larger social and ecological drivers that impact those value chains (Ericksen 2008; Ingram 2011). Drivers that change food systems can be also found within the systems structures (internal drivers) (see Bene et al. 2019)

management (Rotmans et al. 2001), the MLP has emerged as one of the key theoretical frameworks in sociotechnical transition research (Köhler et al. 2019; Geels 2019). Of these main frameworks, MLP can best be used to capture the complexity of large-scale, long-term system transitions and has been used to describe such changes in agrifood systems (for an overview, see El Bilali 2019).The main idea is that transitions can be understood as an interplay of three different levels: (i) the regime level, representing the structures and actors of the current mainstream; (ii) the niche level, representing smaller spaces somehow protected from the regime; and (iii) the landscape level, representing long-term macro drivers that impact both regime and niches (Geels 2002). For food systems, the regime level shapes the core activities of the current incumbent food system by providing stable structures such as markets, knowledge, policies, norms, technologies, etc. (Geels 2004; Smith 2007). Incremental innovations including sustainable intensification can take place at that level. Niches in food systems are places that follow different rules and structures. In niches, more radical innovations are found that can represent novel technologies (e.g., the pioneering of cultured meat), but also innovations that focus on social and agroecological aspects (e.g., novel prosumer initiatives). Depending on the circumstances, such novelties can be taken up by the incumbent food system or disrupt it (Geels 2004). The landscape level of food systems includes long-term trends such as climate change, biodiversity loss, or globalization that affect incumbent and emerging food systems, by creating pressures or also favorable conditions for them. Pending on the circumstances, a transition can take the forms of different pathways (Geels and Schot 2007; Geels et al. 2016):

- Transformation: slow pressures from landscape level and absence from radical niche alternatives lead to the gradually adjustment of the regime to cope with new conditions.
- De-alignment and re-alignment: severe and fast landscape pressures lead to disruptions in the regime. The lack of available niche substitutes leads to a competition of several niche innovations. It takes time till another steady state is reached.
- Technological substitution: mature niche technologies that can become dominant following changes on landscape level.
- Reconfiguration: agile regime actors take over innovations from niches.

MLP originated in the field of socio-technical transition theory and was developed to explain large-scale technological transitions by considering not only technical, but also social factors. Traditionally, the MLP had little future orientation and was used to research past transitions (Vähäkari et al. 2020), such as the transition from horse-pulled cart to automobiles (Geels 2005) or from sailing to steam boats (Geels 2002). Later efforts were also made to use MLP for exploration of the future. The most explicit approach is socio-technical scenarios (STSc) (Hofman et al. 2004; Pregger et al. 2020; van Bree et al. 2010; Verbong et al. 2010), where the MLP is used to create speculative, qualitative scenarios about future transition pathways of niches struggling against regimes both embedded in particular landscapes (Geels et al. 2020).

However, to our knowledge, participatory scenario approaches play only a very minor role in STSc.[2] The creation of future scenarios with the participation of multiple stakeholders also plays an important role in transition management, which is inspired by MLP. However, the visioning process in transition management focuses on the creation of desired positive visions that provide guidelines for future actions (see e.g., Loorbach 2010; Nevens et al. 2013) and therefore follows more a visionary mode of thinking (De Smedt et al. 2013) or a "normative" scenario approach (see Börjeson et al. 2006 and below). In contrast to that, the participatory scenario approach we use follows more an exploratory approach to anticipate future changes, risks, and opportunities (see below). Another recent attempt is the work of Vähäkari et al. (2020), who formally linked MLP with the main concepts of future studies at an abstract level. Our research partly builds on that linkage and continues the effort by providing a more detailed rationale for how concrete techniques and concepts from both fields can be combined.

In contrast to traditional MLP research, participatory scenario development often aims to exceed the boundaries of academic science and is widely used in transdisciplinary research (Oteros-Rozas et al. 2015; Schneider and Rist 2014; see e.g., Scholz and Tietje 2002), which focuses on real-life world problems, the interdisciplinary integration of knowledge, and the participation of involved stakeholders (Hirsch-Hadorn et al. 2008a, p. 29). The reason for the popularity of participatory scenario development in transdisciplinary research is that it allows for the integration of knowledge from different stakeholders and helps to understand the current situation as well as future developments (Hirsch-Hadorn et al. 2008b; Wiek et al. 2006). In addition, the process itself serves important functions in that it can bring together people from different backgrounds and motivate people to take action to promote the desired future change (Chermack and Lynham 2002; Chermack 2004; Wiek et al. 2006). Although most formative participatory scenario

[2] To the best of our knowledge, only Leloup et al. (2022) aimed to create STSc using a participatory approach. However, their approach does not really utilize or discuss the different aspects of the MLP framework.

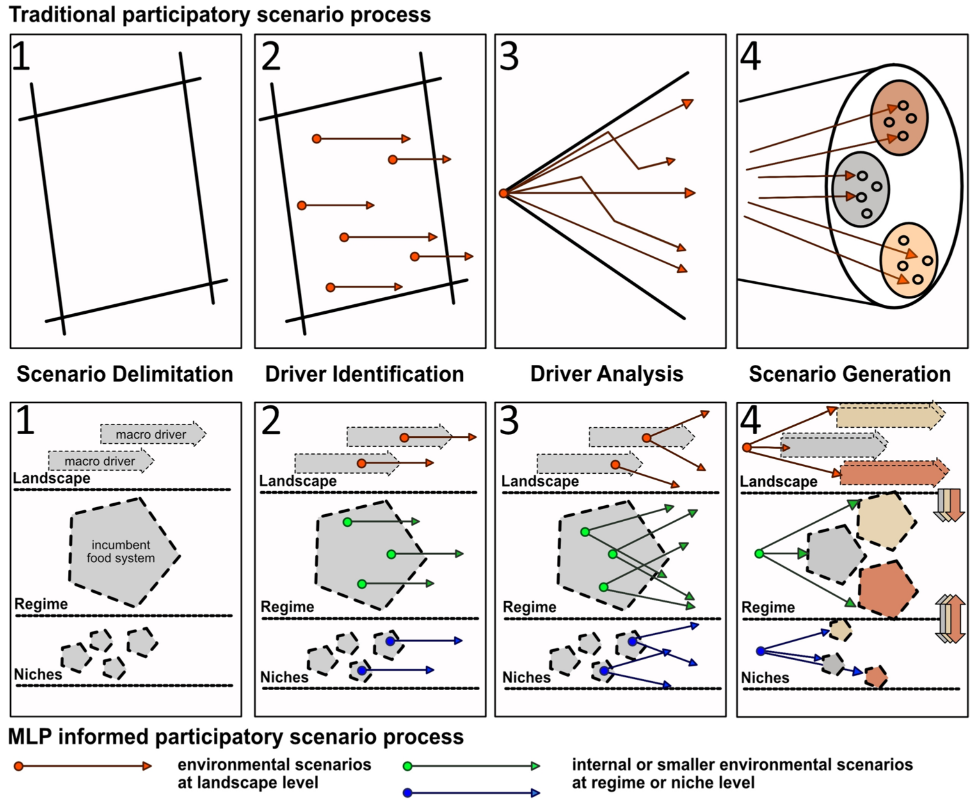

Fig. 1 Main working steps for scenario development and integration of the MLP framework

approaches are based on a systems framework (see below), they typically do not use the more detailed MLP framework. For example, recent studies on European food systems did not distinguish between the different levels of food system transitions (Fink and Michel 2020; Moller et al. 2020; Mora et al. 2016; Mylona et al. 2017; Vervoort et al. 2016). Here, only López Cifuentes et al. (2023) use the MLP as an underlying framework for their project, but the consequences for the creation of scenarios are not discussed in detail. In the following, we provide an outline how to integrate participatory scenario development in the MLP framework (see Fig. 1 for illustration).

Various approaches to scenario development exist. For example, Börjeson et al. (2006) distinguish between three types of scenarios that are used to answer different questions: e.g., to find out what might happen (exploratory scenarios), what will happen (predictive scenarios), and how a certain state might be realized in the future (normative scenarios). All three types of scenarios can theoretically be developed using a variety of more or less formalized techniques (see Bishop et al. 2007) and with different degrees of stakeholder participation (Wiek et al. 2006). In transdisciplinary scenario projects, scenarios are often exploratory, external stakeholder participation is high, and a mix of intuitive and formative techniques[3] is frequently used (see e.g., the overview from Oteros-Rozas et al. 2015). Therefore—without denying that other approaches may also be useful—in this article we focus on a more formative, exploratory scenario approach in the tradition of Gausemeier (1998) and transdisciplinary case studies (see e.g., Scholz and Tietje 2002). Therefore, we define a scenario as "[…] a coherent description of a possible future situation that is based on a complex net of influential factors" (Gausemeier 1998, p. 90). Following this definition, we consider a scenario as a future state of a current system of interest. What the future state looks like depends on the development of the key drivers, which represent important (mega)trends. In exploratory scenario development, several different futures are generated. Creating and comparing these different futures can help anticipate risks and opportunities and explore possible development paths (Chermack 2004). In participatory scenario development, the decision who is included in the process is crucial and stakeholder involvement must be carefully managed. Although there are of course variations in

[3] Formative methods are formalized and involve clear rules for ratings, calculations, and derivation of results. Intuitive methods on the other hand rely more on the expert or tacit knowledge of participants and are based on less strictly formalized creative or discursive techniques. In scenario development, it is common to apply a mix of formative and intuitive methods: Gräßler et al. (2019), Wiek et al. (2006).

general, the development of exploratory scenarios consists of four major steps (Wiek et al. 2006):

Step (I) is the demarcation of the scenario field. Here, the system of interest and the time frame for the scenarios are defined. Then the decision is made whether the scenarios illustrate possible change in that interest itself (so-called internal scenarios), or whether the scenarios should depict possible changes in environment of the system of interest (so-called external or environment scenarios). A combination of internal and external changes is also possible (so-called system scenarios) (Gausemeier 1998). Step (II) is the driver identification. Here, the key drivers must be selected. Key drivers are elements of the system of interest or its environment that are most important for the future development. In the terminology of future studies, they represent trends or megatrends (Vähäkari et al. 2020). Key drivers can be selected based on their systemic characteristics (interconnectedness, impact on other system elements) or other criteria that are of importance of the involved stakeholders. Step (III) is the driver analysis. Here for each key driver, possible future developments in the given time frame under different assumptions are identified. The analysis should take past developments into account, but also be open to surprising changes and—at least in transdisciplinary projects—always involve a degree of creativity. Step (IV) is the scenario generation. Here, the various possible driver developments must be combined into a small number of consistent and relevant scenarios, and coherent narratives/stories are developed. Each combination represents a possible future state of the system of interest or its environment, which is further described by the narrative. Consistency, in turn, can be achieved through certain formalized techniques (e.g., computer-assisted consistency analysis) or through deliberation by the actors involved (discursive approach).

Participatory scenario development is a flexible approach that can be integrated into the MLP framework in a variety of ways by locating the "system of interest" at different levels. The system of interest can be an established (regime level) or an emerging (niche level) socio-technical system. The key drivers for scenario development may be found in the structures of that system (e.g., trends regarding markets, knowledge structures) or as megatrends at the landscape level (cf. Vähäkari et al. 2020). Internal scenarios show how a socio-technical system might evolve at the regime or niche level over a given time frame. Drivers for scenario development represent key structural conditions of the system, such as dietary habits or farming technology. Environment scenarios can also describe changes at three levels of the MLP. Most likely, environment scenarios will describe changes at higher levels than the system of interest and discuss possible consequences for the system. If the system of interest is at the niche level, environment scenarios may consider important changes at the regime and landscape levels. If the system is at the regime level, the focus is on changes at the landscape level. This means that scenarios show what the landscape level might look like in the given time frame and identify possible positive or negative impacts of these changes on the levels below.

We see that scenarios can illustrate how the three levels of transitions in the food system might evolve in the future and how this might affect other levels. In doing so, the MLP also enhances the explanatory power of the scenarios to explain different aspects of food system transitions, as it explains how the different levels interact with each other and informs about the resulting consequences for the future development of food systems. The four types of transition pathways can also help to understand how scenarios might emerge and what types of changes they represent. For example, the MLP can be used to assess whether scenarios represent a slightly different version of the existing regime or a full-scale system transformation. The MLP can also be used to inform the selection of participants for the scenario process or to reflect on possible consequences. For example, that scenarios could support the status quo, if only regime actors are invited.

An important point is that the transdisciplinary integration of stakeholder perspectives changes the quality of scenarios. As a consequence, the MLP functions less as a "hard" or ontological framework to model reality, but rather as a "soft" or epistemological tool used to create a shared understanding for sustainable transitions (Checkland and Scholes 2007; Ison 2008).

Case studies: food systems and innovations

We illustrate the possibilities of combining participatory scenario development and MLP for the analysis of innovation and their transformative potential by presenting some of the results from the project "Inclusive Food System Transitions" (IFST). This project analyzes the potential contributions of food innovations in Germany, to inclusive and sustainable food system transitions. The projects aimed to analyze innovations, which address technical as well as social dimensions of food systems, which are of relevance for Berlin–Brandenburg and situated at the regime and niche level. Due to the transdisciplinary nature of the project, the selection also depended on available contacts and the willingness of actors to participate. Five specific innovations were considered in this study.

The first innovation is a prosumer citizens' shareholder company (Regionalwert AG (RAG) that enables people to invest their money in regional, environmentally friendly, and socially just businesses along the food value chain. The goal is to provide agrifood businesses with alternative financing options, create connections between consumers and producers, and support sustainable regional development

(Hennchen and Schäfer 2022). RAG represents an alternative and not widely used form of financing and aims for the creation of new relationships between food producers, consumers, and also other actors of food value chains. Therefore, we see it as addressing mainly social aspects at the niche level.

The second innovation includes alternative sources of animal protein. These include the growing sector of plant-based meat alternatives in Germany (PBMAs) and prototypes of cultured meat production. PBMAs are plant-based products that mimic the taste and texture of meat. Cultured meat refers to meat grown from stem cells in bioreactors (Tomiyama et al. 2020). Both are mainly technological innovations, but due to their rapid increase in market share and integration into conventional food chains (see Jahn et al. 2021), PBMAs can be characterized as becoming part of the regime, wheareas cultured meat is still far from a large-scale production stage and therefore a niche.

The third one is a behavioral dietary intervention with the goal that elderly people in Berlin-Brandenburg adopt a healthier diet to prevent health problems.[4] Physicians and dieticians advise participants and support them with healthier food options. Dietary interventions are an established part of the German health care system, but they could be used in a more preventive way. Therefore, this innovation addresses mainly social aspects (change in practice) at the regime level.

The fourth innovation is the establishment of high-quality pork value chains in Berlin-Brandenburg. Stakeholders from different areas of the value chain developed a vision for sustainable regional meat value chains within the framework of the "Brandenburg Way"[5] and are taking measures to implement it. The establishment of regional value chains requires the restructuring of existing value chains, which are strongly export oriented (Ludwig et al. 2022). Since the "Brandenburg Way" involves regime actors, we are concerned here with technical and social dimensions of food systems at the regime level.

The final innovation is the introduction of more inclusive and healthier school lunch programs in Berlin secondary schools. Several stakeholders are trying not only to promote incremental changes in Berlin's school lunch programs to provide healthier and more sustainable food, but also to increase the number of students participating in the school lunch program. School meals could theoretically contribute to healthy, sustainable diets and food literacy, but their potential is often not used (Morgan and Sonnino 2013). The redesign of school meals addresses mainly social aspects at the regime level.

These innovations are part of the German food system, which is highly developed, increasingly specialized, concentrated, and embedded in international trade (Schrode et al. 2019). Similar to other Western industrial food systems, it is also characterized by high capital intensity, a large share of urban consumers, and long and complex value chains (see Marshall et al. 2021). Furthermore, the German meat industry in particular is highly export oriented and dependent on international markets (Ludwig et al. 2022). This system cannot be classified as sustainable, but faces several challenges, such as the exploitation of natural resources, diet-related health problems, or problematic working conditions (Schrode et al. 2019).

The capital region of Berlin–Brandenburg is home to 6 million people. Berlin is known for its progressive consumers and has a huge market potential for regional, sustainable food products (Doernberg et al. 2016). However, thus far, the direct creation with the agricultural hinterland of Brandenburg remains comparably low. The innovations being considered here address several challenges. For example, the introduction of healthier school meals or nutritional interventions can improve food literacy and address diet-related health problems. Prosumer initiatives and the Brandenburg Way can help establish sustainable regional value chains and reduce dependence on international value chains. Alternative protein sources can make food production less resource intensive and reduce meat consumption.

Environmental scenarios were created that describe how the landscape for all food innovations could evolve by 2040. The scenarios show potential changes for key external drivers at the landscape level and are then used to discuss the impacts on relevant food systems and to explore potential development paths of the food innovations.

Data collection and analysis

In the project IFST, researchers from different disciplines created several scenarios in collaboration with non-academic actors to generate findings that are relevant for both academia and practice (Hirsch-Hadorn et al. 2008a; Lang et al. 2012). Wiek et al. (2006) distinguishes between strategic actors, who define the goals for a scenario project and design and facilitate the process, and operational actors, who participate in the actual scenario development process. The strategic actors were three scientists who were responsible for scenario development in IFST and two principal investigators of the project. The operational actors were composed of: (i) researchers and (ii) practitioners involved in the food innovation case studies; (iii) other practitioners and experts from relevant food systems, such as representatives of farmers, the food industry, or public administration. The researchers involved in the case studies invited appropriate practitioners, which represented niche or regime actors

[4] Refer to: https://endokrinologie.charite.de/forschung/adipositas_und_diabetes/nutriact/.

[5] Refer to: https://www.neuer-brandenburger-weg.de/.

Table 1 Participants involved and working steps of the scenario process

Working tasks	Number of participants			
	Strategic actors	Operative actors		
		IFST researchers	Case study practitioners	Food system experts
Demarcation of field	5			
Workshop 1: driver identification	3	12	6	7
Impact analysis	3	2		
Workshop 2: driver analysis	3	11	6	7
Workshop 3: scenario generation	2	8	4	5
Interviews: impacts on food innovations	1	5	5	

pending on the type of innovation. The strategic stakeholders invited the additional external food system experts with the aim of bringing a wide range of different perspectives to the process (for a more detailed description of the participants, see Box S12/Supplementary material). In total, 38 people were involved in the scenario development (Table 1). The group of participants remained the same for all three workshops. Participants who were unable to attend a workshop were given the opportunity to provide written feedback.

All four main steps of scenario development were framed according to the MLP. The demarcation of the scenario field was done by the strategic actors. The remaining steps were conducted primarily through two online workshops in autumn 2021 (due to COVID-19 restrictions) and one in in-person workshop in May 2022. Strategic actors facilitated the workshops, documented the results, and conducted additional work tasks and analysis. A mix of formative and intuitive techniques were used. Workshops included group tasks using a variety of techniques. Moderation of the tasks was done by the strategic actors. Decisions in the groups and in the plenaries were made by consensus. However, participants had the opportunity to document remarks and comments. The minutes and the documented results of each workshop were again shared with all participants, and they had the opportunity to comment on them. Critical points or changes were discussed in the next workshop. The focus of the first workshop was the driver identification. Participants formed groups and conducted a STEEP analysis (Fisher et al. 2020). STEEP analysis provides a systematic framework for identifyingthe most important factors in the social, technological, environmental, economic, and political environments of a system of interest. First, participants brainstorm all possible influencing factors in the five environments. In a second step, the list is harmonized so that all influence factors are on the same level of abstraction. Finally, the factors are rated in the order of importance, and the most important ones are selected for further strategy development. In the workshop, each group worked on one environment and consisted of IFST researchers, case study practitioners, and external experts. The end result of each group's work was four key drivers that they felt were the most important influence factors. The drivers were further discussed by all workshop participants and rated according to their relevance to food systems and the uncertainties associated with them.

After the first workshop, the strategic actors and two IFST researchers conducted an additional impact analysis following Gausemeier (1998). Here, participants created an impact matrix by rating the strength of each driver's influence on all other drivers (0 = no influence; 1 = little influence; 2 = medium influence; 3 = strong influence). Based on this rating, the "active sum" (the sum of the influences on all other drivers) and (ii) the "passive sum" (i.e., the sum of all influences of other drivers on this driver) for each driver are calculated. With these two indicators, it is possible to identify critical drivers (i.e., drivers with high active and passive sums), which are likely to have a large influence on the future development of the system. Based on the evaluation of the first workshop and the results of the impact analysis, 10 drivers were selected as key drivers. Those drivers should qualify as critical drivers and also should have been assessed as important by the participants. At the beginning of the next workshop, this pre-selection was presented and discussed and defined with the participants.

In the second workshop, the driver analysis was carried out using mainly intuitive methods. Five groups, made up of a mix of scientists, practitioners and experts, developed different ways in which two key drivers assigned to them could develop over the next 20 years. To do this, participants were asked to take three steps. First, they collected possible newspaper "headlines" for the year 2040 that described the state of each key driver. Hereby they were asked to think out of the box and also choose surprising headlines. Second, participants defined possible developments of the drivers addressed in the most relevant headlines. Third, these developments were peer reviewed by other participants (i.e., results were critiqued and supplemented). The results were then presented, discussed, and refined in a plenary session.

Due to the sudden outbreak of the Ukraine crisis after the workshop, additional adjustments were made by the strategic actors and two additional factors (international conflicts and volatile markets) were added.

In the final full-day workshop, scenarios were developed using a discursive approach. Four mixed groups were formed, each of which came up with three consistent combinations of key-driver developments. Consistency was achieved through discussion between group members (discursive approach). For each combination, the groups developed a short scenario story. This way of creating scenarios pushes people to think outside the box and familiar narratives. The draft scenarios were presented to the plenary session. Participants selected four scenarios that best represented the diversity of the portfolio presented and developed detailed narratives explaining how the drivers will evolve through 2040 for each scenario. Finally, the groups discussed the potential implications of the landscape scenarios for food systems.

After the workshops, 10 additional qualitative interviews were conducted with researchers and practitioners involved in the food innovation case studies (Table 1). Interviewees were asked about the potential risks and opportunities for their innovation in the given scenarios and how the food innovation might evolve under these circumstances. Interviews were conducted and recorded online and lasted between 31 and 68 min. The recordings were transcribed. The transcripts were analyzed using qualitative content analysis (Kuckartz 2012), to identify risks, opportunities, and potential development paths for the innovations, as well as the role of landscape drivers.

Results

Possible future landscapes

Participants identified 12 key landscape drivers in five environments of food systems (see Table 2). These drivers represent those landscape-level megatrends that participants identified as having the greatest impact on the food systems of interest. By definition, these drivers are relevant to many socio-technical systems, but will have specific impacts on different food systems depending on how the drivers evolve (see below in the scenario description).

For each of the driver, various possible developments were identified. For a more detailed description of the drivers and their potential developments, see Box S1 and S2 in the supplementary material. Depending on how these drivers develop in the future, and on the consistency of those developments, four scenarios were derived (Table 3).

Scenario 1 was defined as the "Hyggelige Way" ("Hyggelig")[6]: In this scenario in Germany, sufficiency- and quality-oriented lifestyles enable a reinvention of regionalized and "renaturalized" economic systems. However, this regionalization does not go hand in hand with encapsulation. Where necessary, effective trans-local exchange and trade take place.

Scenario 2 was defined as "High-tech Eco-Control" ("High-tech"). In this scenario, new technologies and digitalization determine life in 2040 in large parts of the world. Technological development enables efficient use of resources, but also centralized control of social and economic life. Internationally, there will be a division into regions that are able to partake in the digital revolution and regions that are unable to do so.

Scenario 3 was defined as "Crisis as Risk and Chance" ("Crisis"). In this scenario, social and economic action is characterized by great uncertainty. Various groups are striving to link the crisis with different approaches to solving it. In essence, this can be boiled down to the question: opening up to new ideas vs. regressive tendencies.

Scenario 4 was defined as "Business as Usual" ("BUA"). In this scenario, Europe has muddled through to 2040 without any major crises, but is not on the path to sustainability. This may take its toll in the future because no major structural adjustments have been made. Internationally, Europe has lost importance, but can still offer its citizens a comparatively high level of prosperity.

The detailed scenario narratives can be found in Box S3, S4, S5, and S6 in the supplementary material. Each scenario represents an image of how the landscape of food systems might change. These pictures differ in the severity of the landscape changes. While in the "BUA" most drivers change only incrementally, in the "Crisis" scenario rapid shocks and severe changes dominate the landscape. Similarly, in the "Hyggelig and "High-tech scenario", the landscape changes strongly, but with less uncertainty than in the "Crisis" scenario. The MLP informs us how these different environments could affect innovations at the regime and niche levels, leading to different transition pathways. For example, the "Crisis" scenario, with its severe shocks, is likely to lead to regime de- and realignment, whereas the "BUA" scenario is more likely to lead to transformation or reconfiguration, depending on how agile regime actors in different food systems react and how niche–regime relationships are established. However, the specific impacts will depend on the type of food system in which innovations are embedded.

Possible development pathways of food innovations

Using the MLP framework, it was possible to take a closer look at how changes in the landscape of the food system could affect food innovation at the niche and regime level.

[6] Danish word popular in Germany meaning "cozy".

Table 2 Short description of identified drivers

Type of environment	Driver	Short description
Social environment	Socio-cultural diversification and values	The extent to which society diversifies into social subgroups. Those subgroups can hold different values, follow different lifestyles, and are shaped by different norms, cultures, and traditions
	Civil engagement	The form and extent to which civil society engages with societal concerns Engagement can take more or less institutionalized forms (from bottom-up initiatives to established advocacy groups). A higher level of engagement is expressed in more collective or political action
Technological environment	Technological development	The established level of technology Depending on the level, more high-tech (i.e., digitalization, artificial intelligence, biotechnology, etc.) or low-tech (i.e., more manual work, handcraft, analog production processes) technologies are used
Ecological environment	Climate change	The increase in global average temperature and associated climatic and meteorological effects, as well as ecological, social, and economic consequences
	Ecosystems and biodiversity	The state of ecosystems, including the extent of biodiversity as one of their central characteristics
Economic environment	National economic inequalities	The economic inequality in Germany as well as the general level of economic prosperity
	Global economic inequalities	The economic differences at a global level (between north and south, and western and non-western countries)
	Globalization of value chains	The extent of globalization of economic systems, which is expressed by the length and complexity of value chains and the status of international trade
	Stability of global resource markets	The volatility in (global) resource markets that are relevant for food systems. Secure markets are characterized by stable supply, demand, and prices
Political environment	Economic policies	The developments in the policy fields that frame economies at different levels. This includes the processes and democratic structures within which decisions are made
	Environmental policies	The environmental policies and developments in the policy fields that frame emissions and the use of natural resources at different levels. This includes the processes and democratic structures within which decisions are made
	International conflicts	The extent of international conflicts. Conflicts can be prevented through effective international cooperation. If this is not possible, conflicts can be settled diplomatically or with armed force

We see that the scenarios helped participants envision radically different development paths and the resulting roles that innovations could play in transforming food systems (Fig. 2). They identified landscape developments and associated changes in food systems that present different risks and opportunities for the innovations. The most important of these landscape developments appear to be climate change, technology, national economic inequalities, value chain structure, volatile markets, civic engagement, societal values, and global inequalities (again, see the electronic supplementary material for a detailed overview). Below is a brief description of how food innovations might evolve in the different scenarios. Due to space limitations, we can only describe three innovations here. The description of the other two (regional value chains and dietary interventions) as well as a more detailed description of possible transition pathways can be found in Box S7, S8, S9, S10, S11 in the supplementary material.

Alternative proteins Cultured meat is seen here as a technological innovation, still at the niche level, while PBMAs are increasingly becoming part of the regime. Because of their different status, they are affected differently in the scenarios. In the "Hyggelig" scenario food systems are likely to change heavily due to the changing context and PBMAs could be an important part of diets, because of the overall higher importance of plant-based food products due to an extensification of agriculture. However, PBMAs won't mimic traditional meat products, because of changing consumer values, small scale production chains and technology in use. Instead PBMAs will not be highly processed, but produced with traditional low-tech methods. These changes could be described as reconfiguration, since PBMAs are currently part of the regime, but are being modified to fit the

Table 3 Driver developments in the scenarios

Key drivers	Hyggelige way	High-tech eco-control	Crisis as risk and chance	Business as usual
Socio-cultural diversification and values	A diverse and integrated society; sufficient lifestyles are dominant	Lifestyles are increasingly driven by digital control options	Climate, and political crises lead to increased refugee movements	Diversification of lifestyles through ongoing individualization and migration
Civil engagement	High engagement and participation of civil society	Social life takes place on digital platforms and is thereby controlled	Division: different groups engage only for their own benefit	Engagement is there, but so are signs of disintegration between different groups
Technological development	Re-invention of traditional crafts, decreasing industrialization	Rapid technological development; digitization of all areas of life	Crisis leads to progress in certain areas, in others to stagnation due to shortages of resources	Moderate technical progress; digitization plays a major role
Climate change	Successful adaptation to + 1.5° with "low-tech" measures	Successful adaptation to + 1.5° with "high-tech" measures	Failed adaptation due to uncertainties/crises	Successful adaptation until 2040 but no strategy for thereafter
Ecosystems and biodiversity	Renaturation of ecosystems; space for preservation/wilderness	Ecosystems are heavily used, but through new technology, largely sustainable managed	Environmental degradation and overshooting of ecosystem tipping points	Increasing use of ecosystems; separation into areas for production and conservation
National economic inequalities	Small inequalities because highest incomes decrease	Income disparities rise; people without access to digital services become marginalized	Economic inequalities between crisis winners and losers rise sharply	Economic inequalities widen in line with previous trends
Global economic inequalities	Living conditions between the global north and south are increasingly converging	World regions that are losing touch with digitization become impoverished	Crises exacerbate differences between global north and south	Inequalities between north and south intensify; BRICC countries catch up
Globalization of value chains	High regionalization of value chains	Global value chains, but increasing isolation of non-digital regions	Crises disrupt global value chains and lead to shortages	Globalized, unstable value chains; new players from emerging markets
Stability of global resource markets	Stable, regional markets; larger markets are fragmented	Relatively stable markets due to digital control and high productivity	Uncertainties and high volatility in markets; supply often unclear	Volatile markets with price fluctuations
Economic policies	Effective multilateral standards; growth-dampening policy	Effective multilateral standards, growth-enhancing policies	Nations try to enforce their national interests	Inter-, and national policy focus on competition and free markets
Environmental policies	Effective and profound environmental policy at national and international level	Ecological modernization; high focus on technical solutions	Environmental and climate protection are being scaled back	Ecological modernization of production processes
International conflicts	Conflicts are successfully preempted by international diplomacy and institutions	Mutual deterrence of geopolitical blocs; diplomacy is necessary	Warlike confrontations are becoming more common	Intensive diplomacy can only halfway keep conflicts at bay

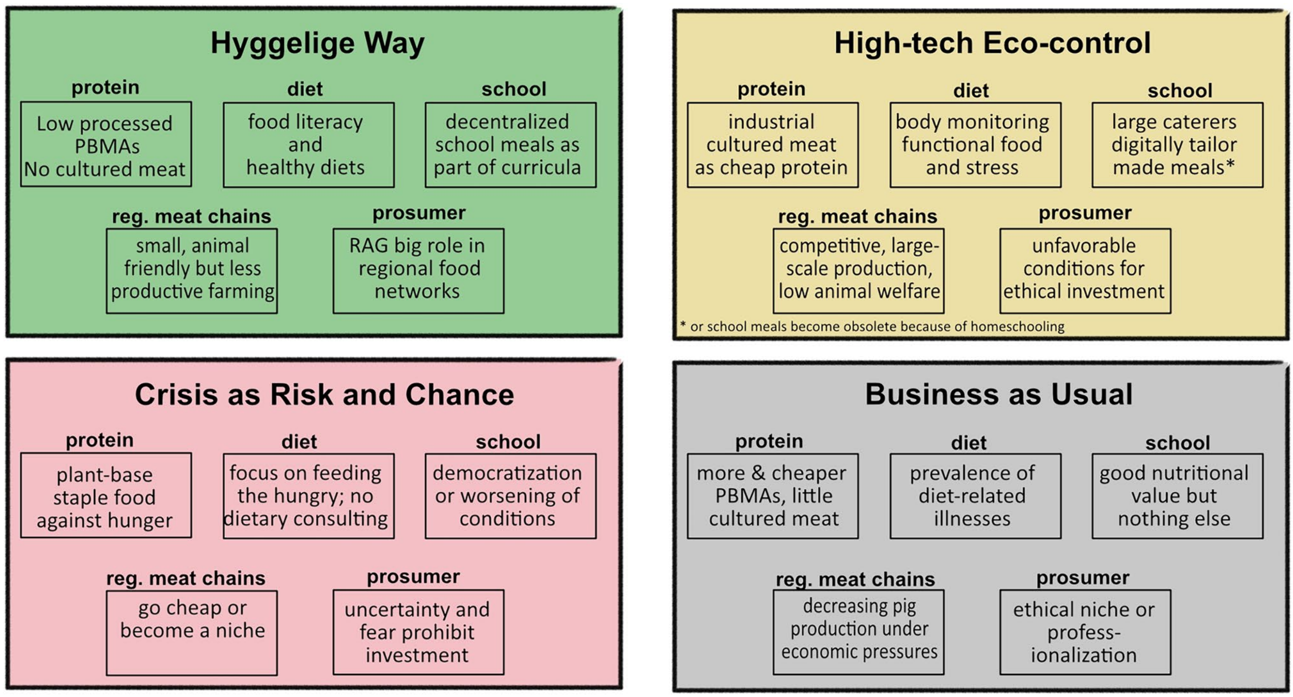

Fig. 2 Possible developments of food system innovations in scenarios

new context. Due to social preferences, and the technology used cultured meat will not play a role in this scenario. In the “High-tech” scenario rapid technological progress and highly centralized value chains are creating the conditions for large-scale, efficient production of cultured meat. Cultured meat is needed as a cheap source of protein as climate change reduces the productivity of traditional agriculture and creates global inequalities. People also have a positive attitude toward high-tech foods. This scenario provides very favorable conditions for the technological substitution of traditional industrial meat products with cultured meat. PBMAs on the other hand play a minor role due to the comparative advantages of cultured meat. In the “Crisis” scenario there will be no opportunity for elaborate PBMAs that mimic meat products, and most likely no cultured meat. Instead, the goal is to provide people with plant-based staples to fight hunger caused by climate change, ecosystem destruction, conflict, and flight. In MLP terminology, what we have here is a de-alignment due to shocks, but what the re-alignment might look like is still unclear. If the crises are not too severe, they could give a boost to cultured meat research. For the “BUA” scenario interviewees saw a growing sector for PBMAs (especially if they become cheaper than meat products), but little opportunity for cultured meat due to complicated production processes and consumer reluctance. PBMAs are less and less likely to try to imitate traditional meat products. Since there is little change in the landscape, we find little change in the regime. The steady growth and minor changes in PBMAs could be seen as a "weak" transformation.

School meal programs School meal programs are already established at the regime level and the innovation aims to transform these programs to make them more inclusive and healthier. The "Hyggelig" scenario offers opportunities for decentralized school food programs (regional value chains, reduction of economic inequalities, and high citizen participation). School structures and daily routines would need to be changed to allow cooking in schools with student participation to accommodate large workloads. Nutrition would become a cross-cutting issue in the curriculum. Larger caterers would face difficult conditions due to smaller value chains and the technology used. Changing landscape conditions would allow school meal programs to be reconfigured by adopting several ideas currently practiced in niches, such as school gardening or community-supported agriculture. In the “High-tech” scenario highly efficient large-scale caterers could provide school meals that could be adapted to pupils’ taste and made healthier (through the control of pupils’ diets) using digital tools. School meal programs would be centralized, and school lunches would be still a hectic, anonymous event. Alternatively, digitization could make school lunches obsolete due to the increasing importance of homeschooling. These changes represent a "weak" transformation from the current situation and an adaptation of school lunch programs to take advantage of new technologies. The "Crisis” scenario offers opportunities for greater democratization of school meal programs, but there is also a risk that already disadvantaged schools with low funding and low civic participation will fall further behind as the state reduces support. If crises worsen, school meal programs could become a necessity to provide children with adequate nutrition. Participants see also opportunities for school meal programs to take up niche ideas in the face of crisis. Thus, the outcome could be similar as in the “Hyggelig” scenario, but with more severe disturbances. In the "BUA" scenario, little will change in the status quo: the nutritional quality of the school lunch will be good, but the school lunch will not be particularly healthy, regionally produced, or a social experience. School meals will be delivered by large caterers, while food and cooking are not integrated into the school day.

Regionalwert AG (RAG) The RAG represents an alternative way of financing farms and agri-food businesses outside the traditional regime structure and therefore qualifies as an innovation at the niche level. The “Hyggelig” scenario is not considered to be very realistic by the interviewees. However, if the scenario becomes reality, it would provide very favorable conditions for RAG. Regionalized value chains, local food networks and a strong position of agroecological agriculture are in line with RAG's goals. RAG could take an important position in these new food systems and become a significant way of financing. In doing so, it becomes part of the reconfiguration of the current food regime. Many aspects of the “High-tech” scenario, such as globalized, concentrated value chains or the intensive use of agricultural land or increasing economic inequalities, will hinder the further development of RAG because there are fewer investors and investment opportunities. Theoretically, RAG can still work, and digital methods could help bring consumers and producers together. It's likely that the RAG will remain a niche and that its impact on the regime will remain small. “Crisis” scenario: if the crisis becomes the status quo and fear dominates interactions between people, then RAG will no longer be able to function because people are unlikely to invest in RAG. The move away from globalization and the increased focus of politicians on national interests could open up some opportunities for RAG if this leads to the support of closed national value chains. Thus, it seems that the RAG is not ready enough to propose a clear alternative in the de-alignment of the regime. However, perhaps in the even further future its position could be strengthened. “BUA” scenario: if the current investment strategy continues (i.e., focus on ethical investments that do not yield returns), RAG will grow slowly and attract only a limited number of investors from a particular milieu. Moreover, this investment strategy is complicated by increasing economic uncertainties in the growth-oriented economic system. If RAG is professionalized and the investments secure at least a small return, RAG Berlin-Brandenburg could grow rapidly. The view here is that if the RAG becomes more aligned with current regime structures, it could become part of the regime. If not, the small changes in the landscape and the regime do not allow a window of opportunity for the RAG to expand.

Discussion

The aim of this article was to demonstrate the value of using MLP-inspired participatory scenario development for transdisciplinary research on sustainable food system transitions. To discuss this value, we want to briefly reflect on two questions: First, whether the participatory approach is useful for MLP research and second, what are the benefits of using MLP in transdisciplinary scenario development. We also reflect on practical and policy recommendations derived from the findings, as well as challenges and limitations of this research.

Participatory scenario development as an opportunity for multi-stakeholder engagement in MLP research

Engaging multiple stakeholders in sustainable transition research is often required by scholars (e.g., Rotmans et al. 2001; Grin et al. 2010) and including transdisciplinary approaches to ensure this engagement is still considered necessary (Köhler et al. 2019). Bringing transdisciplinary, participatory scenario development into this research field therefore seems promising. However, one of the main criticisms could be that the scenarios created are not based on scientific analysis, but partly on the preferences of practitioners, and could therefore be highly biased and therefore of little value. Indeed, participatory scenario development is based on the expertise of participants, but our results show that the scenarios are far from being heavily distorted. First, the list of identified landscape drivers has similarities with key external drivers for European food systems identified in other exploratory scenario projects (see e.g., Mylona et al. 2017; Vervoort et al. 2016) as well as in expert driven, top-down approaches such as the socio-economic pathways (SSPs)[7] (O’Neill et al. 2017) or scenarios for or European food systems (Mitter et al. 2020).[8] For example, Vervoort et al. (2016) identified poverty and economic inequality, environmental degradation, technological and social innovation activity, power concentrations, international trade and resource availability as external drivers. Also, the created scenarios themselves share similarities with other scenarios created in participatory and

[7] SSPs (see O’Neill et al. 2014) have become a widely used frameworks to anticipate potential future developments in Europe. The pathways represent 5 possible scenarios how conditions in Europe could develop in the future.

[8] Top-down approaches may of course include more key drivers than participatory, often workshop-based, scenario approaches. Nevertheless, we would argue that the identified landscape drivers cover at least most of the aspects mentioned in scenario work related to SSPs.

expert-driven research projects. For example, the 'Hyggellig' scenario shows similarities with "the price of health" scenario of the Transmango project (Vervoort et al. 2016) or the "regional food" scenario (Mylona et al. 2017). Also, three SSPs for European agriculture ("agriculture on established paths", "agriculture on separate paths", "agriculture on high-tech paths") (Mitter et al. 2020) show proximities to the "BUA", "Crisis" and "High-tech" scenario.

These overlaps suggest that despite their specific focus, the participatory scenarios are congruent with a broader body of knowledge about food system developments and could be therefore useful for exploring potential food system transition pathways. Consequently, participatory scenario development can be a promising tool for MLP research if the process is properly managed and if the implications of a participatory approach are considered and communicated.

Benefits of bringing MLP into participatory scenario development

Concerning the potential of using the MLP for participatory scenario development, we first want to answer the question of whether it is a suitable framework for integrating academic and non-academic perspectives. Second, we will elaborate how the MLP can enhance the traditional framework for participatory scenario development in the tradition of Gausemeier (1998) or Scholz and Tietje (2002).

Regarding the first question we have shown that the MLP framework theoretically offers sufficient possibilities to integrate various approaches of scenario development that are often used in transdisciplinary research. Also, the framework proved suitable for bringing together a range of different stakeholders and integrating their perspectives. Participants agreed on key landscape drivers, while scenarios were also agreed upon by consensus. Third, the process produced tailored scenarios that are of interest to participants, but do not contradict the wider existing body of knowledge. For example, the identified drivers of the IFST scenarios focus heavily on inequalities and sociocultural factors, but not so much on traditional demographics. Fourth, the landscape scenarios created allowed participants to anticipate very different development paths and associated risks and opportunities for their respective food innovations (Fig. 2). In this way, participants also reflected on the impacts of landscape drivers, which can broaden their perspectives on food system transitions: "Talking gets me somewhere […] also to continue these trains of thought somehow. So, when do you ever have the chance to philosophize so completely freely about how our world, our society can continue?" Interviewee AP2 (own translation).

Regarding the second question, Vähäkari et al. (2020) have argued that there is promise in combining futures studies and MLP. Here, we explored this promise further by focusing on additional potential benefits of MLP-informed participatory scenario planning. One of the functions of exploratory participatory scenarios is to enable participants to think about potential future opportunities and risks (Wiek et al. 2006). The use of the MLP framework can enhance this function by increasing the explanatory power of the scenarios, because it can link the changes described in the scenarios to other aspects of food system transitions. The traditional framework for participatory scenario development (Gausemair 1998; Scholz and Tietje 2002) does not provide guidance how environment and systems of interest interact in the scenarios. In contrast to that, the MLP provides a clearer picture by specifying the interactions between the landscape, regime, and niche levels. This allows participants to think about how the changes described in the environmental or systems scenarios play out in transitions and to anticipate additional dynamics, opportunities, and risks. In our case, it was possible to think about how environmental scenarios at the landscape level affect different food innovations at the regime and niche levels.

Policy and practice recommendations

According to the UNESCO (2023) and also to scholars (see e.g., Kates 2011) sustainability science should not only be research about sustainability but also help to promote it. In this vein, the approach here presented can be a useful lens in the toolbox of research on sustainable food systems, because it enables various multiple actors to come together and create a shared understanding of the dynamics of food system transition, explore various futures and anticipate risks and opportunities for food systems and food innovation.

This qualifies MLP-informed participatory scenario development as a suitable approach for developing joint food strategies that are accepted by different actors and take into account bottom-up initiatives as well as the structural context. Such strategies can be important for the implementation of transformative policies, which face the challenge of fostering a variety of bottom-up innovations in the face of uncertain circumstances and competing interests (Jacob and Ekins 2020). In addition, MLP-informed scenario planning can also enable the development and implementation of transformative policies, as the so-called transformative capacities,[9] such as transformative leadership or multiform governance, of relevant stakeholders and organizations could be enhanced through their participation.

Also, the concrete results of the IFST scenario process are of value for future policy actions in Germany and beyond. The process provides two major insights. First, it shows that food systems are not only impacted by technical, ecological and economic factors, but also by a variety of social

[9] i.e., the competencies and resources needed to manage and promote sustainable system transformation (Wolfram 2016).

megatrends. Innovations that address not only technological but also social aspects of food systems play therefore an important role and have to be considered in strategies and policies. Second, the scenarios show that under different circumstances different food innovation can thrive and scale up. Considering the huge complexity and uncertainty connected to landscape development it seems wise to over rely on a single innovation, but to nurture a diverse portfolio of innovations to be ready when the situation demands it (see also Jacob and Elkins 2020).

Although landscape drivers are, by definition, factors that are difficult for food system actors to influence directly, the research shows that it would be foolish to ignore such drivers because they can strongly shape the future pathways of food innovations and food systems. Innovators would therefore do well to consider possible future landscape changes, and many are likely to do so. However, since the results have shown that a variety of innovations are needed to drive sustainable change under different conditions, it seems useful to create opportunities where representatives of different innovations and other food system actors can discuss how to deal with changing circumstances. New cross-sectoral organizations such as food councils, which can play a mediating role between different levels and sectors of the food system (Schiff et al. 2022), may be appropriate places for such reflection at the local level. Similar to visioning processes used in transition management, such an approach could be "institutionalized" in living labs or transition labs (see Nevens et al. 2013) linked to these councils. However, the challenge remains how to institutionalize such approaches at the national or international level.

Challenges and limitations

One limitation of this research is that the participatory scenario process was mainly restricted on the creation of the landscape scenarios themselves. Although potential landscape effects of food systems were discussed in the third workshop, the main information on how different food innovations could develop under various scenarios was collected through interviews. This was necessary due to limited resources within the project and shows the considerable effort that is needed to conduct a scenario process that covers all level of food system transitions. Due to the limited number of interviews, these results should be considered exploratory in nature. They do not represent an exhaustive list of possible pathways, but rather illustrate how scenarios can help to anticipate changes.

Second the large number of food innovations considered in this research proved also a challenge, because it made it harder to identify landscape conditions that are relevant for all of them. Also, the selection of food innovations partly depended on the availability of contacts and the willingness of stakeholder to participate in the research process. In the future it could be beneficial to focus on a narrower sample of case studies that follows more specific hypotheses.

Third the concept of the MLP is also not easy to communicate to practitioners in detail and often it is hard for participants to clearly differentiate between the three levels, which points to the difficulty to distinguish them also conceptually as separate entities (see e.g., Fuenfschilling and Truffer 2014). Also, it proved sometimes hard to define in the process to which degree an innovation is part of the regime or niche, and we acknowledge that our decisions in this regard could spark debate. In this vein, the systematic collection of feedback from practitioners on their understanding of the MLP would have been beneficial but was not done in this research.

Finally, a strength of the MLP is that the framework can raise awareness about the differences between niche and regime level actors, which should be considered in the selection of participants to ensure that a multitude of perspectives are represented. We tried to follow the idea, but regime actors were slightly overrepresented in our research (see Box S12 in the supplementary material).

Conclusion

In this article, we presented an approach for integrating MLP and participatory scenario development and applied to a study in which multiple stakeholders developed scenarios for how the landscape of five specific food system innovations might evolve through 2040 in Germany. The participatory scenario process allowed the identification of key landscape developments and their implications for food system innovations. This helped participants explore potential development paths for food innovations. The outcome of the process is a comprehensive overview of how five currently relevant food innovations might evolve under different circumstances, which can help anticipate their potential role in the transition to more sustainable food systems. Findings also highlight the benefits of having a diverse set of food innovations ready to account for changing circumstances.

The results also show the value of incorporating participatory scenario development into MLP research and vice versa. Although the scenarios produced are not solely based on a thorough scientific analysis, they are still of value because they incorporate specific expertise from a variety of stakeholders, which allows for the creation of tailored scenarios. We have shown that the participatory scenarios do not substantially contradict the results of other, more expert-driven scenario approaches. Nevertheless, the participatory scenarios are of course not an "objective" forecast of the future. Consequently, MLP becomes less of an ontological framework and more of an epistemological tool used by “communities of inquiry” to prepare for the future and create desirable visions and pathways.

We also demonstrated that participants were able to develop a shared understanding of possible future landscape developments and that the scenarios enabled participants to reflect on their food innovations. The MLP framework can increase the explanatory power of traditional participatory scenarios for the exploration of food system transitions. Based on these findings, we suggest that MLP-based participatory scenario development is promising for research on sustainable food system transitions.

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